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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

PRIORITY DOCUMENT

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Electrophoretic display device

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Electrophoretic display device

The invention relates to an electrophoretic display as specified in the precharacterizing part of claim 1.

Display devices of this type are used in, for example, monitors, laptop computers, personal digital assistants (PDA's), mobile telephones and electronic books.

The E Ink-type electrophoretic display is based on the motion of charged colour particles in a clear fluid under influence of electric field, as schematically shown in Fig. 1. All particles and fluid are closed in microcapsules. When a negative voltage is applied to the top electrode, the positive charged white particles will move to the top surface, creating a display having a white state (paper-like state, all light coming in is fully reflected). When a positive voltage is applied to the top electrode, the negative charged black particles will move to the top surface, creating a display having dark state (ink-like state, all light coming in is absorbed). Apparently, the switching time is a function of the distance between the top and bottom electrodes and the motion speed of evolved particles.

Electrophoretic display is superior to other display technologies such as LCD in terms of brightness, optical contrast, viewing angle and power consumption. It has paper-like readability. It is suitable for applications such as electronic books or electronic reader. However, the present E Ink-type electrophoretic display is NOT suitable for applications for video or motion picture because of its low switching speed! For example, the minimum switching time required for a transition from full black to full white is typically in the order of 150ms. This is about a factor of 10 longer than the required maximum allowable time for a picture update in a real time video, which is typically 16ms!

It is an object of the invention to provide a display device of the type mentioned in the opening paragraph which provide proper display of video and motion pictures.

To achieve this object, a first aspect of the invention provides a display device as specified in Claim 1.

Such a display device enables the **display for video/motion pictures** by operating at a temperature above the ambient temperature (25 °C) or preferably above 35 °C. The invention is based on the recognition that the switching time of the electrophoretic display is largely shortened at higher temperature as will be shown below.

Figure 2 shows representative experimental results of a recent E Ink sample (sample 91, PHG150102), for two types of transitions: Type-I transition: starting at 30L* (almost full black) and ending at 58L* (close to white); Type-II transition: starting at 32L* and ending at 50L*. A voltage of -15V is used in these experiments. It is clear that the switching time decreases exponentially with increasing temperature! A minimum switching time of 47.5ms is obtained for type-I transitions and of 33 ms for type II transitions. This is now very close to video speed.

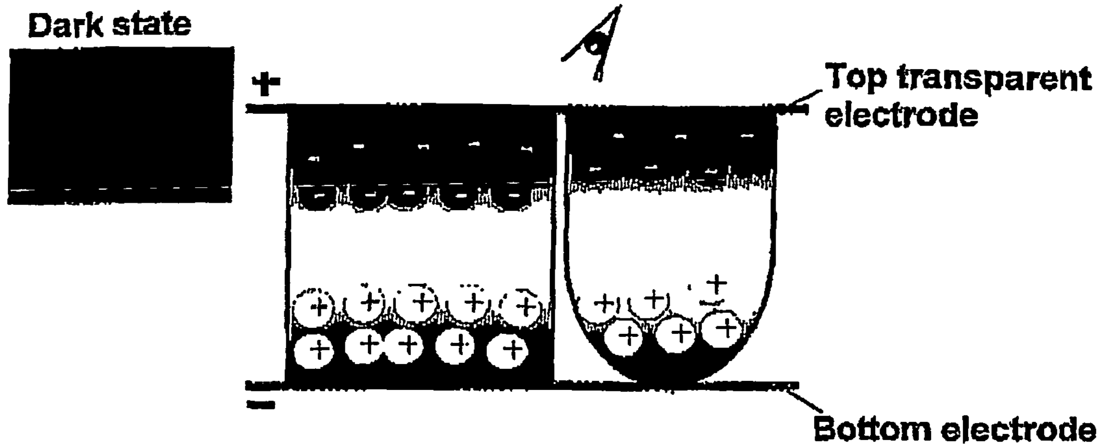

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Figure 1: Schematics of the present E Ink type electrophoretic display.

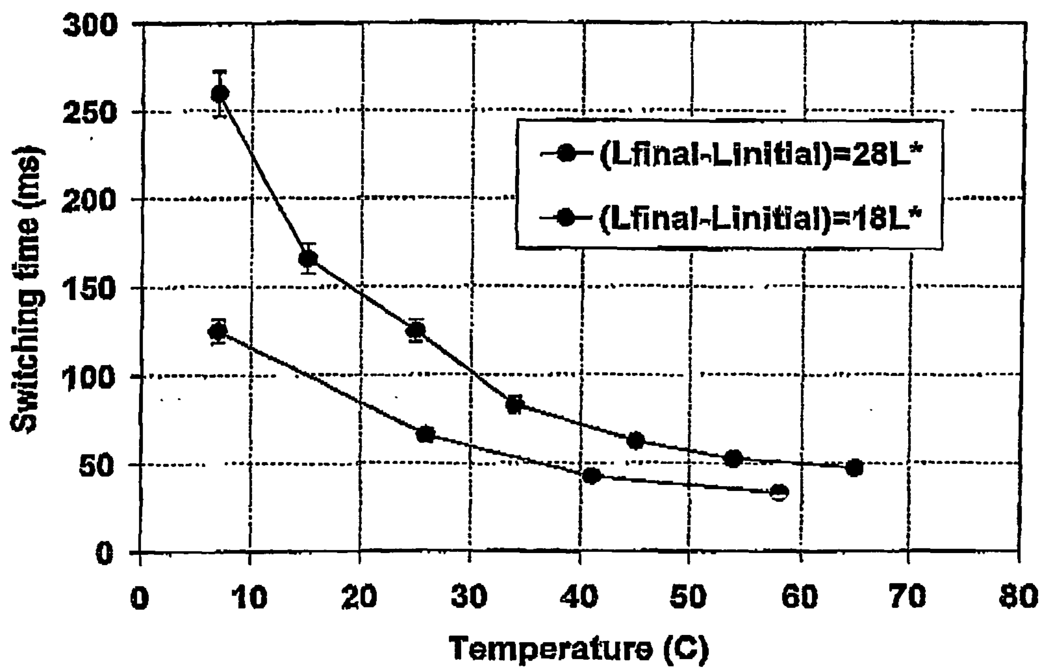

Figure 2: Representative experimental results for two types of transitions: Type-I transition: starting at 30L* (reflectivity: 6%, almost full black) and ending at 58L* (reflectivity: 30%, close to white); Type-II transition: starting at 32L* and ending at 50L*. In both cases, the switching time decreases exponentially with increasing temperature.

The fact that the switching time decreases with increasing operating temperature is a result of competition between the increased particles mobility and the drop of voltage across the capsules due to a decreased electric resistance by fast ions motion in the fluid. The higher mobility results in a higher switching speed. However, the reduction of the electric resistance by fast ions motion results in a voltage drop (increase of leakage) or a low switching speed. Apparently, at a temperature up to at least 70 C, the particles mobility plays a dominant role, resulting in a higher switching speed. We propose to use this big advantage creating an electrophoretic display **also suitable for video applications! Heating elements are integrated to an electrophoretic display**. Following are some example embodiments (other possible implementations containing heating elements are not excluded).

Example embodiments

Embodiment 1: The heating element is direct in contact with the bottom electrode and the bottom electrode is also acting as a thermal conductor as shown in Fig.3. The advantage of this embodiment is easy to implement. But it works only when the electrode material has sufficiently high thermal conductivity. A temperature probe is added to the display at the backside of the bottom substrate, which may also be on the same side as the heating element. A controlling element is arranged for reading out the signal of the temperature probe and regulating the heating power to maintain a fixed temperature (not drawn in the figure).

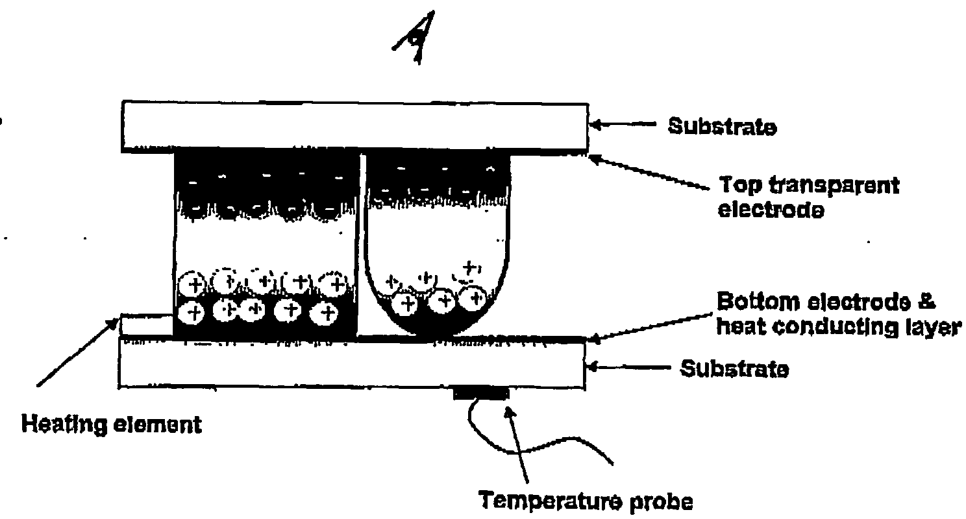

Figure 3: Illustration of embodiment 1 according to this invention. Heating element is in direct contact with the bottom electrode. A temperature probe is added.

Embodiment 2: An additional heat-conducting layer is placed on bottom electrode, on which the heating element is integrated as shown in fig.4. Again a temperature probe is arranged.

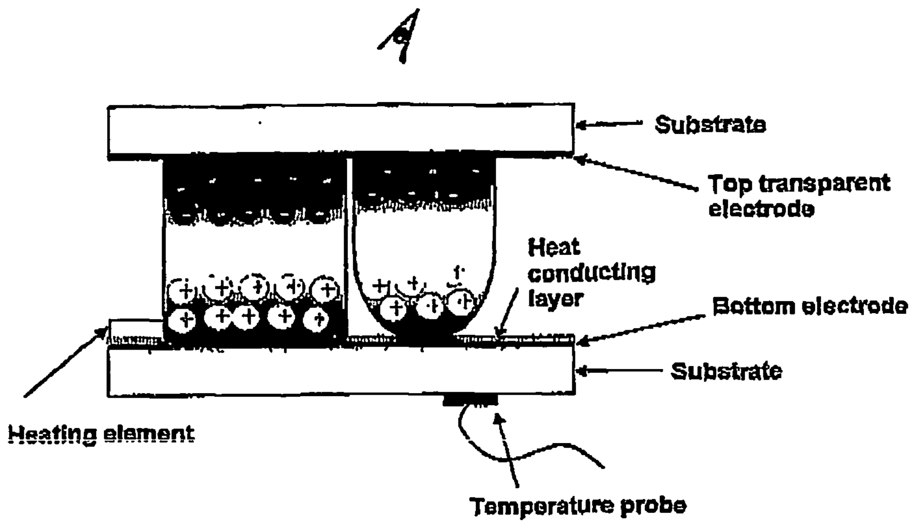

Figure 4: Illustration of embodiment 2 according to this invention. An additional heat-conducting layer is placed on bottom electrode, on which the heating element is integrated. Again a temperature probe is arranged.

Embodiment 3: The additional heat-conducting layer is placed on the backside of the bottom substrate, on which the heating element is integrated as shown in fig.5. Again a temperature probe is arranged.

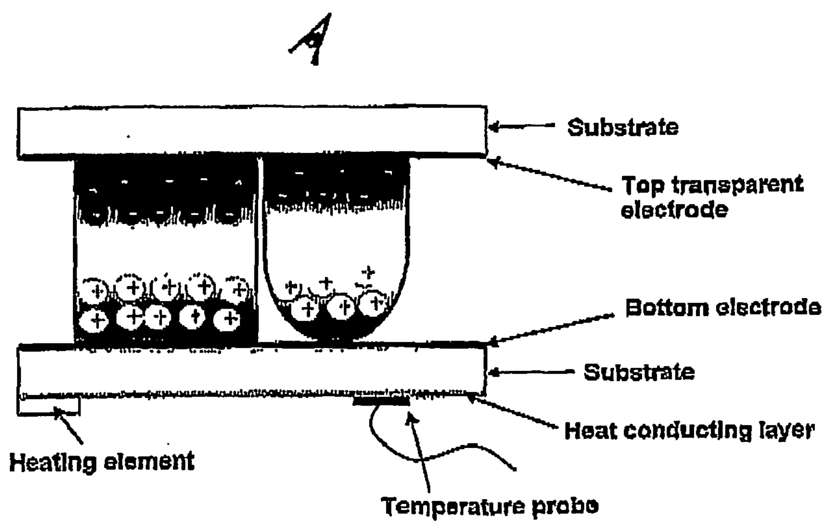

Figure 5: Illustration of embodiment 3 according to this invention. The additional heat-conducting layer is placed on backside of the bottom substrate, on which the heating element is integrated. Again a temperature probe is arranged.

Embodiment 4: The "Peltier element" is used as the heating element as shown in Fig.6. This holds also for embodiments 1 and 3.

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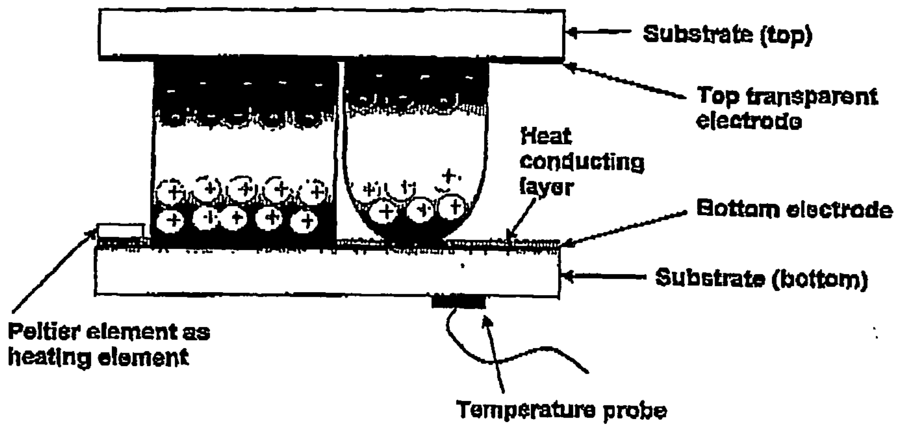

Figure 6: Illustration of embodiment 4 according to this invention. An additional heat-conducting layer is placed on bottom electrode, on which the Peltier element is integrated a heating element. A temperature probe is arranged

Embodiment 5: A heating foil or coil is used as heating element, placed on bottom electrode as shown in Fig.7. The advantage of this embodiment is that no heat-conducting layer is required. Cost saving! Again a temperature probe is arranged.

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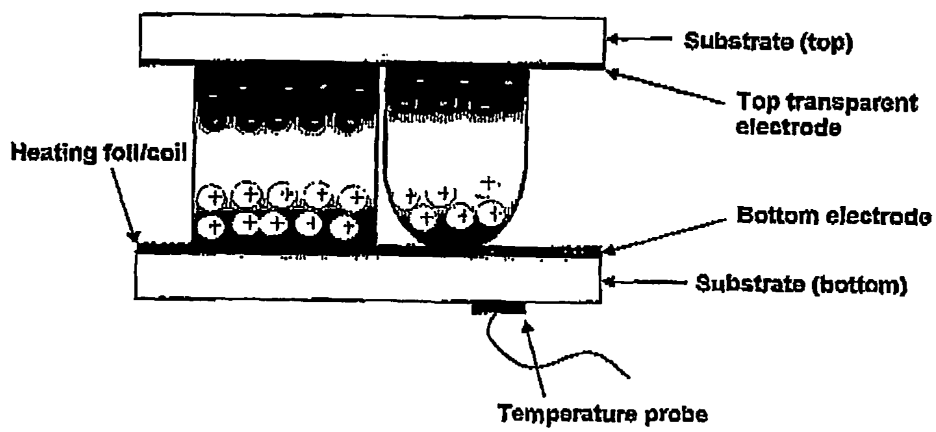

Figure 7: Illustration of embodiment 5 according to this invention. A heating foil or coil is placed on bottom electrode. A temperature probe is arranged.

Embodiment 6: The substrate especially the bottom substrate is chosen from a heat-conducting material such as metal layer as shown in Fig.8.

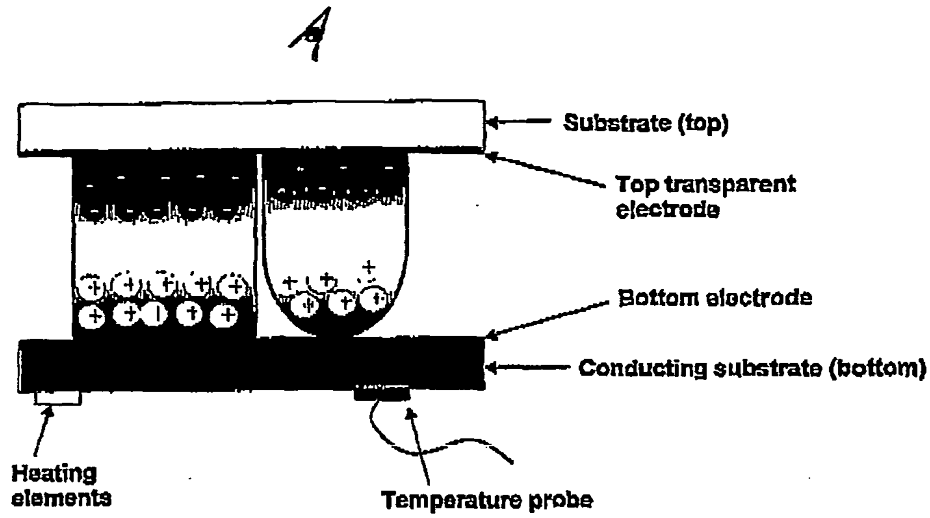

Figure 8: Illustration of embodiment 6 according to this invention. The (bottom) substrate is chosen from a heat-conducting material. A temperature probe is arranged.

Embodiment 7: A housing with heating element as shown in Fig. 9. The whole display is closed in the house. Again a temperature probe is arranged.

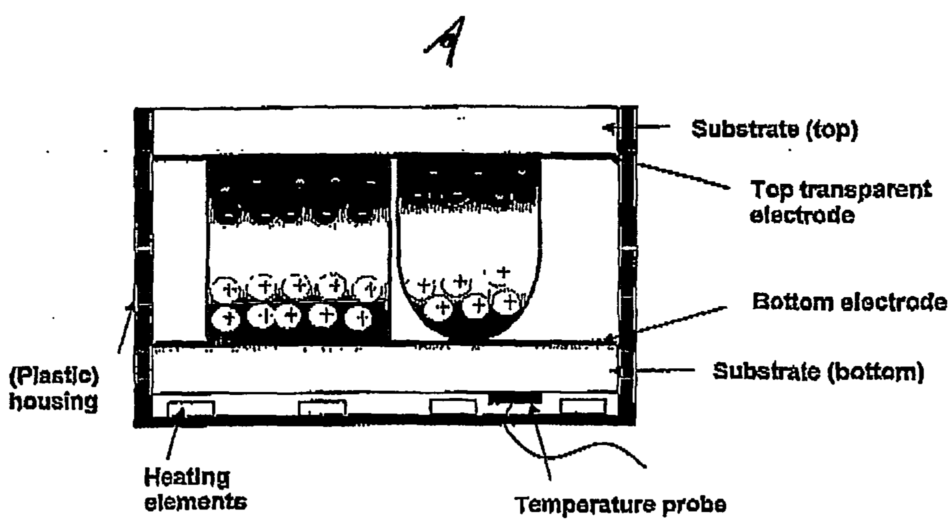

Figure 9: Illustration of embodiment 7 according to this invention. A housing with heating element is placed around display. A temperature probe is arranged.

Embodiment 8: *Multiple heating elements* are used as shown in Fig. 10, in order to obtain a uniform temperature on the display because the switching time is sensitive to the temperature. A uniform temperature results in an accurate transition thus a high quality picture.

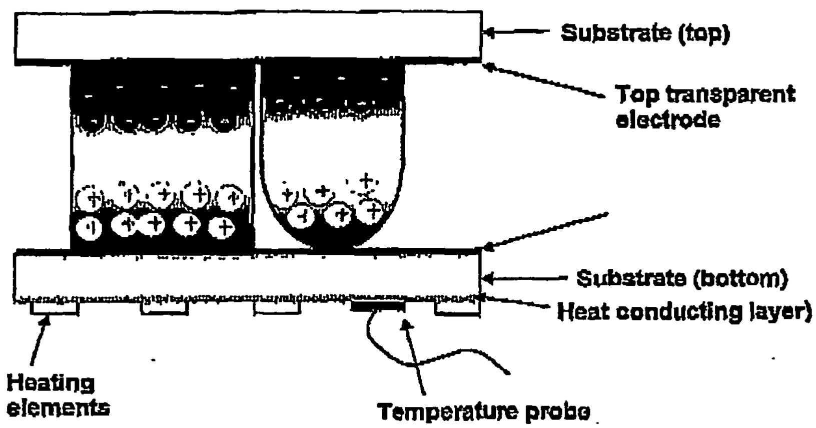

Figure 10: Illustration of embodiment 8 according to this invention. Multiple heating elements are used.

Embodiment 9: *Multiple temperature probes* are used as shown in Fig.11, to maintain uniform temperature or to adjust driving scheme according to the detected temperature.

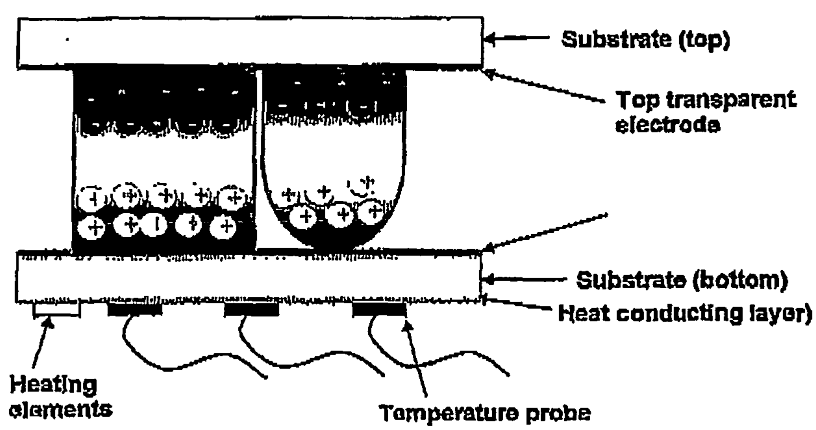

Figure 11: Illustration of embodiment 9 according to this invention. Multiple temperature probes are arranged.

Embodiment 10: The switching speed is expected to be further increased by using even smaller capsules. The size of the capsule of the present E Ink display is in about 30-40 micrometer. A smaller capsule means a smaller distance to move for the particles.

Embodiment 11: Optimising the resistance for highest voltage across the capsule at high temperature. The present ink is optimised for room temperature.

The above embodiments are ONLY examples and other possible layout is not excluded, where the display contains at least one HEATING element.

CLAIMS:

1. A display device comprising electrophoretic particles, a plurality of display element, each display element comprising a pixel electrode and a counter electrode associated between which a portion of the electrophoretic particles are present and control means for supplying a drive signal to the electrodes to bring the display element in a predetermined optical state corresponding to the image information to be displayed, characterized in that display device comprising heating means for heating the display elements to a temperature of in the range between 30 and 70 degrees Celsius.